TEMPERATURE INFLUENCE ON PLANTING AND HARVEST DATES.

By JOSEPH B. KINCER, Meteorologist.

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SYNOPSIS.—(1) There are certain restricted limits of time within which crops must be planted for best results, defined by the temperature conditions of the locality. The length of the time period within which the planting of a given crop may be accomplished decreases in general with increase in latitude.

(2) A definite amount of heat is required after planting to bring a crop to maturity; as a rough measure of this the accumulated day-degrees of temperature above the mean temperature at which planting is accomplished, may be taken. As thus computed there is very little difference in the amount of heat necessary to mature most staple spring planted crops, when the average variety of corn is considered. It is suggested that the mean temperature at which the planting of a given crop can be accomplished be used as a base, or starting point, for any method that may be employed for temperature summation, instead of a general base for all crops. If the frequently used 6° C. base be employed in the case of cotton, for example, we would begin the reckoning of effective temperatures in the vicinity of Abilene, Tex., about three months before planting can begin, with a resulting indicated large accumulation of effective temperature before any growth is possible.

(3) Spring wheat seeding begins with a lower mean temperature than any other major spring crop. Seeding usually begins in the Dakotas and in Nebraska when the normal daily temperature rises to 37° (F.) and in Minnesota and Wisconsin when 40° (F.) is reached. Next in thermal order comes spring oats, the seeding of which usually begins when the normal daily temperature rises to 43° (F.) (corresponding to the advent of the vegetative period). Early potato planting begins as a rule when the normal daily temperature rises to 45° (F.), and corn when 55° (F.) is reached. The dates on which the latter is reached correspond closely to the average dates of last killing frost in spring. Cotton planting usually does not begin until the normal daily temperature rises to about 62° (F.). The dates on which this temperature is reached correspond closely to the latest dates in spring on which killing frost has occurred.

(4) Cotton and corn are warm-weather crops and the areas in which successful production on a commercial scale can be accomplished are limited principally by both the general temperature conditions and the temperature at which planting may be accomplished. These limits are defined by an available thermal constant of about 1,600° (F.) for corn and about 2,000° (F.) for cotton, computed from the normal temperature when planting usually begins. It follows that if cotton could be planted with as low temperatures as corn planting is accomplished, the cotton area would be materially increased.

(5) Owing to the relatively large thermal requirements of corn and cotton, a comparatively warm spring is necessary for best results of germination and early growth. Thus there is a close relation between the spring temperatures and the condition of these crops to certain dates in the early stages of growth.

Those who have occasion to travel from one section of the United States to another and note farm activities in different localities, such as the planting and harvesting of the various crops, are impressed with the wide difference in calendar time of these operations in the northern portions of the country as compared with the southern. These differences are due, of course, to climatic conditions, particularly to the temperature, which varies greatly with the latitude, especially in the winter season. Along the immediate Gulf Coast the normal daily temperature, for example, does not go lower than 52°(F.) in winter, but in northeastern North Dakota and northern Minnesota a daily mean of zero or slightly lower, is reached in mid-winter. The 52°(F.) isothermal line which skirts the Gulf Coast about the middle of January advances northward as the season progresses, reaching western Tennessee about the middle of March, southern Iowa about the middle of April, and the north-central border of the country about the middle of May. In the meantime, the temperature along the Gulf Coast has risen to about 75°(F.), the rate of increase for the four-month period being about half as fast on this coast as in the north-central border States.

Regardless of the particular crop, or locality in which grown, there are certain definite limits of time within which planting must be accomplished for best results; and in much of the country, particularly in the central and northern districts, this period is of comparatively short duration for a given crop. These limits are defined by the temperature conditions of the locality, and while the thermal influence is obvious, the details of its control, or the measure of the significant temperature that tells us when the season for planting a particular crop has arrived, are not so generally known. Consequently, it is the object of this paper to study in some detail certain significant temperature values that seem to establish the average spring planting dates of the principal agricultural products of the country, and also the heat necessary to bring them to maturity after planting. These details of the relation of temperature to planting and harvesting dates are interesting and can often be used to considerable advantage. For example, a farmer contemplating moving from southern Georgia to, say, eastern Nebraska would doubtless know that the proper planting dates for his corn, oats, potatoes, etc., in the new location would differ greatly from those to which he had been accustomed, but he probably would not be aware of the fact that the Weather Bureau records for eastern Nebraska, properly interpreted, indicate the time at which these activities should begin, on the average, in that locality.

A certain amount of warmth is necessary for the germination of seeds, the amount required differing for seeds of different plants. Wheat and oats germinate at a much lower temperature than does corn, and corn in turn requires less warmth for successful germination than does cotton. Thus, some crops may be planted earlier in spring than others. In addition, a definite amount of heat is required after planting to bring a crop to maturity. As a rough measure of this heat there may be used what is known as the "thermal constant," which refers to the total, or accumulated day-degrees in excess of some significant temperature taken as a starting point. Investigators differ as to the temperature value from which the thermal constant should be calculated, but for spring-seeded crops it is believed that the starting point should be the mean temperature at the date of seeding.[1] The method for obtaining the thermal constant is quite simple. For example, if it is desired to compute this value for corn in a locality where the normal temperature is 55°(F.) at the average date of planting, and the mean temperature for any month during the growing season is 75°(F.), the thermal constant for that month would be 75°(F.) − 55°(F.) = 20°(F.), multiplied by the number of days in the month. If the normal daily temperature for any portion of a month should be less than 55°(F.), however, these days should be omitted, and only those days used which have a mean daily temperature of 56°(F.) or higher.

The thermal constant of a particular plant and the temperature at which planting may be accomplished determine whether or not the temperature conditions in a given locality are favorable for its maturity.

While the normal daily temperature at which planting usually begins differs for different plants, these measures are quite uniform for the same plant regardless of the locality, and it follows that when this significant temperature for a particular plant is known, a map may be

[1] See the effect of weather upon the yield of corn by Prof. J. Warren Smith, MONTHLY WEATHER REVIEW, 42, pp. 78–93, February, 1914.

drawn for the entire country based on this value, which will indicate approximately the average safe date for the beginning of seeding. Places in the northern United States where there are more hours of sunshine, other localities where cloudiness is slight, and still others where on account of altitude or dryness the sunlight is more intense, will usually have somewhat lower safe planting temperatures than regions where the summer days are shorter, or cloudier, or where a high moisture content of the air may keep the sunlight relatively weak. This is because soil and plant temperatures depend on sunlight as well as on air temperature. (See pp. 327–328).

The following summary indicates for the country east of the Rocky Mountains the normal daily temperatures at which planting of the more important crops usually begins in spring, and also the dates on which the temperature rises to these values in the different sections of this area. The planting and harvesting dates used for determination of the corresponding temperatures are based on numerous reports collected by the Bureau of Crop Estimates and the Office of Farm Management. (See O. E. Baker, C. F. Brooks, and R. G. Hainsworth, "A Graphic Summary of Seasonal Work on Farm Crops," Yearbook of the U. S. Department of Agriculture, 1917, pp. 537–589, 90, figs., see pages 323–327 below.)

FIG. 1. Date in spring when the normal daily temperature rises to 37° in the western spring wheat belt and to 40° in the eastern (corresponding to the average date on which spring wheat seeding begins).

SPRING WHEAT.

The principal spring-wheat belt comprises the States of Minnesota and the Dakotas. From a thermal standpoint spring wheat is seeded earlier than any of the other major crops. Sowing usually begins in the Dakotas and Nebraska when the normal daily temperature rises to 37°(F.), and in Minnesota and Wisconsin when it rises to 40°(F.). Figure 1 indicates the dates on which these temperatures are reached in the different portions of the spring wheat belt. The seeding begins in the southern portion of the belt about the 20th of March and progresses northward at an average rate of about 20 miles a day, reaching northeastern North Dakota and northern Minnesota about the middle of April, the isochronal line keeping pace with the isothermal line indicated. The sowing of spring wheat becomes general about 10 days after the time of beginning.

SPRING OATS.

The successful growth of spring oats is not so geographically restricted as is that of spring wheat, there being more or less of this crop grown in nearly all sections of the United States. The principal spring-oat belt, however (see fig. 2), consists of a crescent-shaped area, extending from New England to North Dakota, bounded on the north by the Great Lakes and on the south and west by a curved line extending across central Ohio, Illinois, eastern Nebraska, and thence northwestward along the Missouri River. Spring oats is the second in order of temperature of the spring crops sown. Seeding begins north of the Gulf States when the normal daily temperature rises to 43°(F.), except in an area comprising Oklahoma, Kansas, Missouri, and the lower Ohio Valley, where it begins while the temperature is about 3°(F.) lower. Seeding begins in the central and southern Gulf States at higher temperatures than 43°(F), due to the fact that the normal daily temperature does not go as low as 43°(F.) in that area. Very little of this crop is grown, however, in these southern districts. It will be noted that spring-oat seeding begins simultaneously with

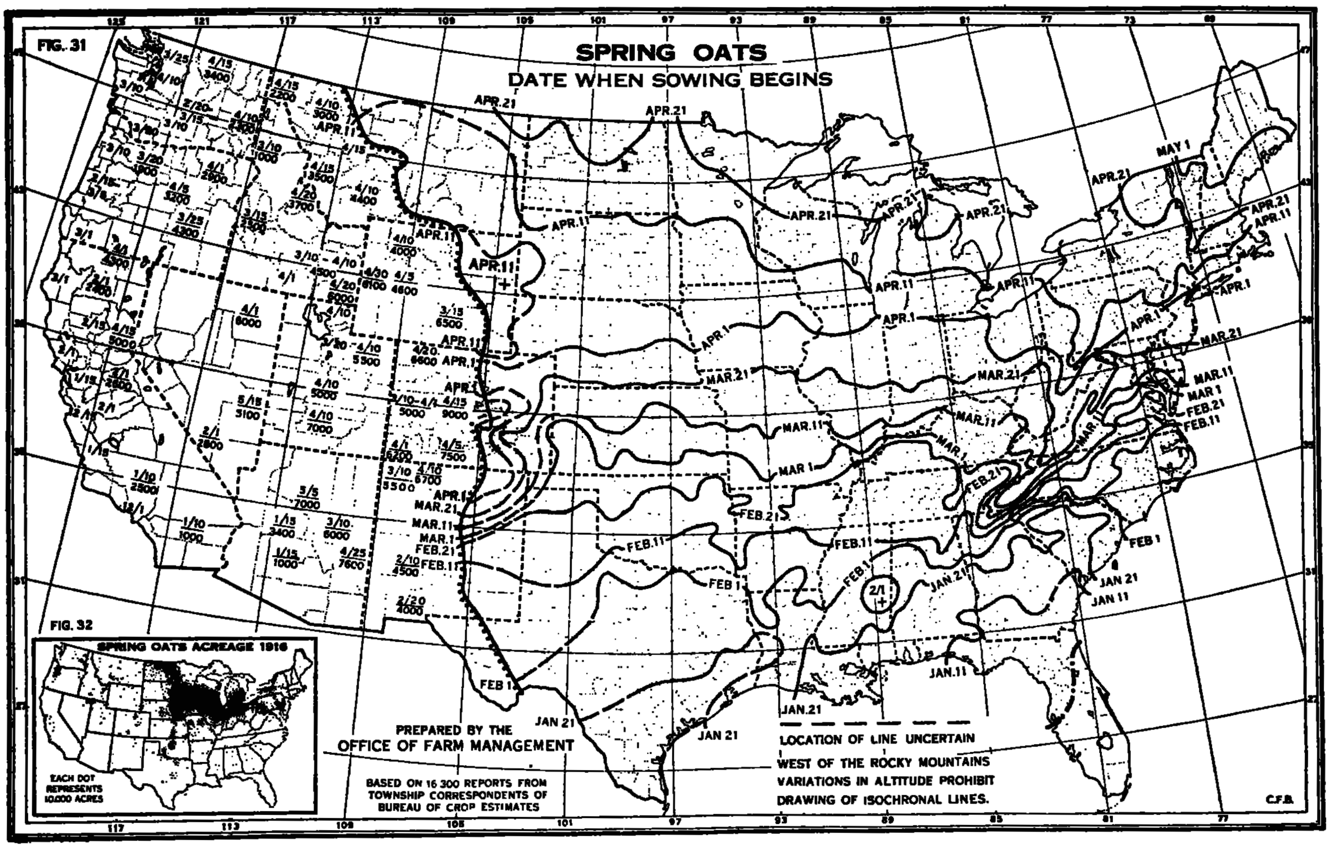

FIG. 2.

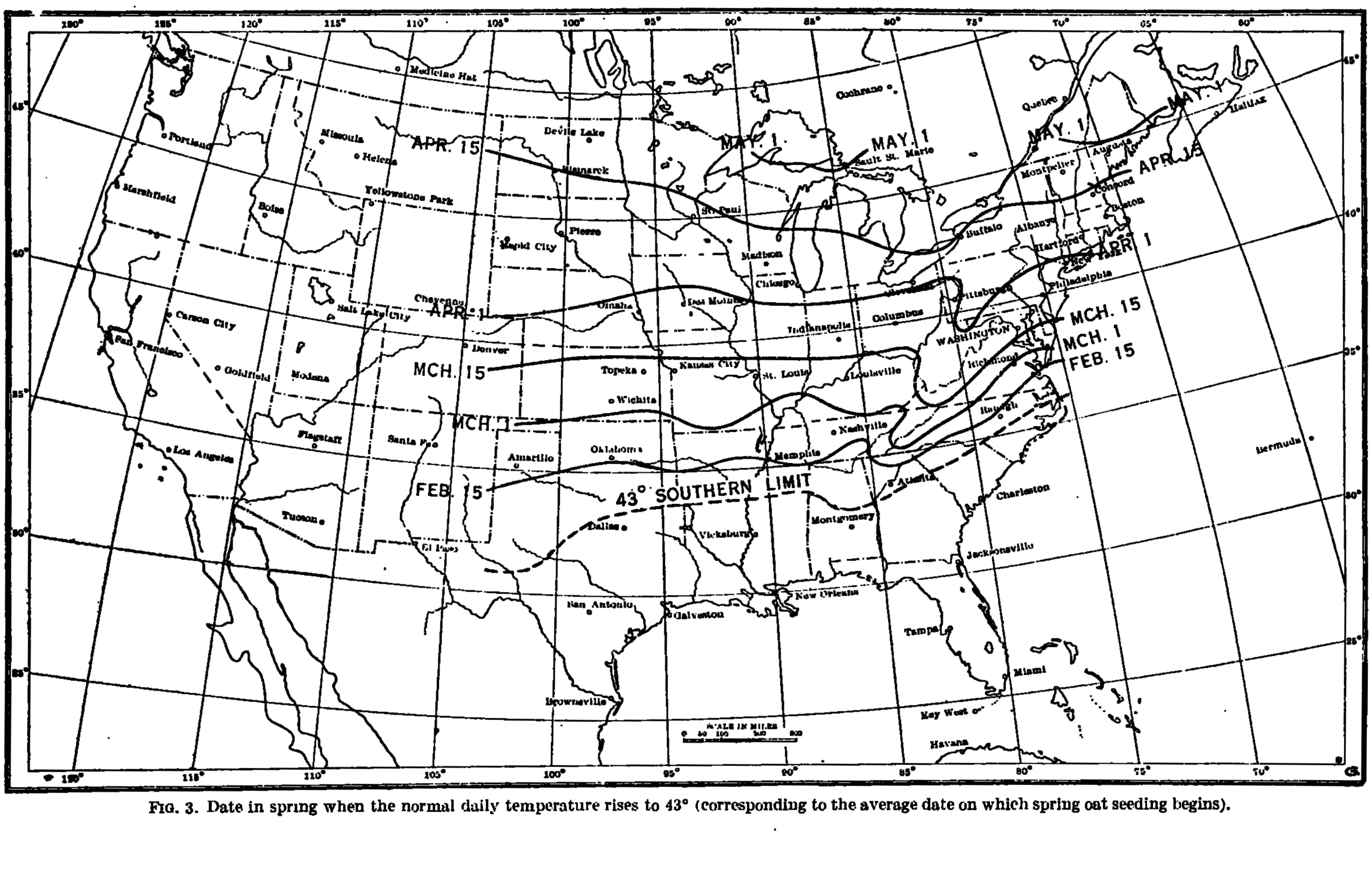

FIG. 3. Date in spring when the normal daily temperature rises to 43° (corresponding to the average date on which spring oat seeding begins).

the advent of the vegetative period in spring; this also corresponds to the time when the normal daily minimum temperature passes above the frost line (32°(F.)).

Figure 3 shows the northward progression of the mean daily isotherm corresponding to the average dates on which oat seeding begins. It will be noted that it requires a period of two months for this work to move northward from central Oklahoma to southeastern North Dakota, an average rate of about 13 miles a day, although the progress is much faster from central Nebraska northward, due to the rapid increase in temperature as spring advances. The dotted line on figure 4 shows the southern limit of the area in which the mean daily temperature falls below 43° (F.) in winter.

the northern border States by May 1. Thus the planting of early potatoes usually begins in northern Mississippi about February 15 and in northern Wisconsin two and one-half months later, but in each locality when the normal daily temperature rises to 45°(F.).

CORN.

Owing to the greater thermal requirements of corn for germination and growth this crop can not be planted until the soil becomes much warmer than is necessary for spring wheat, oats, or potatoes (see fig. 6 and compare with figs. 2 and 4). The temperature at which corn planting usually begins varies slightly for different sec-

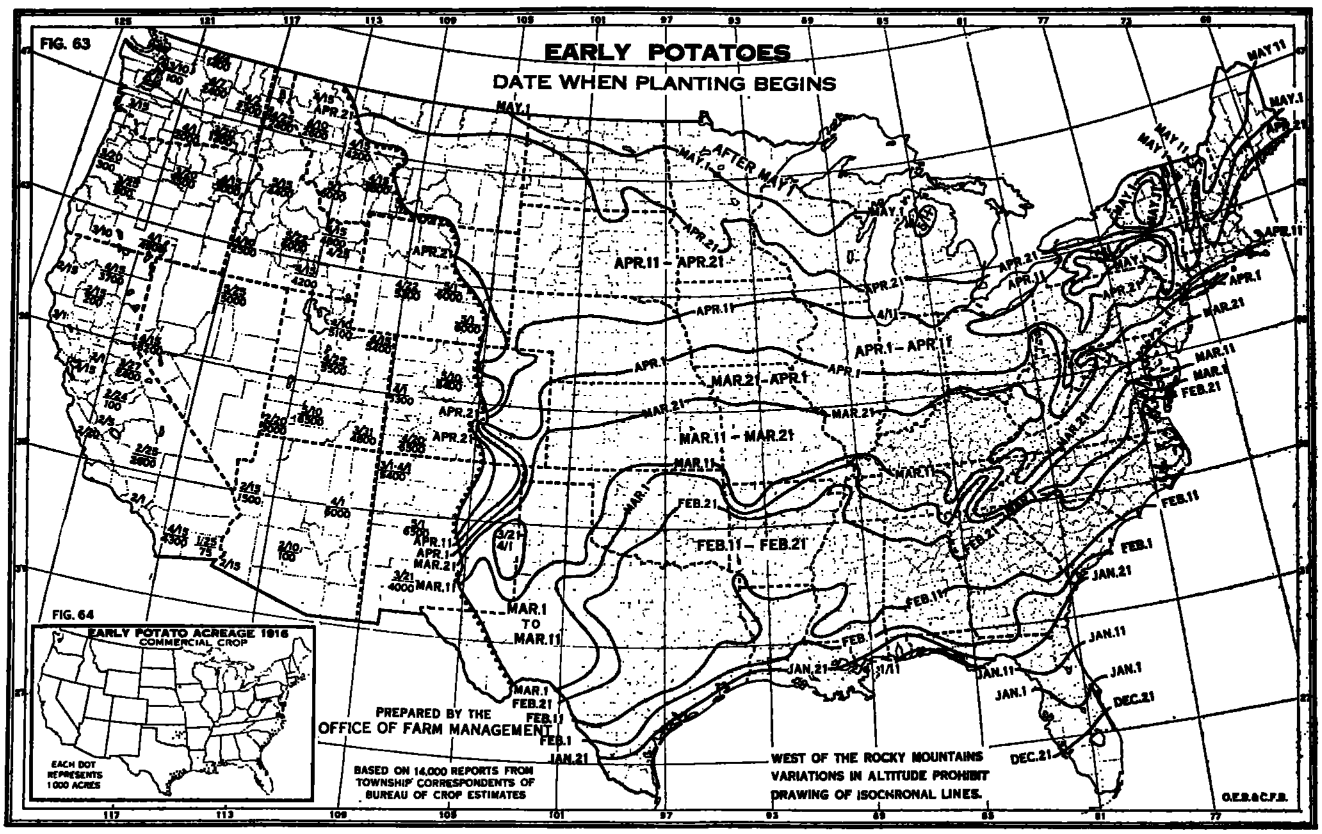

FIG. 4.

EARLY POTATOES.

The normal daily temperature at which early potato planting begins follows soon after that for the sowing of spring oats (see fig. 4). This operation begins, on the average, when the temperature rises to 45°(F.), except in the Gulf coast section where mean daily temperatures as low as this are not reached during the winter. Figure 5 shows the northward progression of the 45°(F.)-isotherm, which corresponds almost exactly to the general progress of the isochronal line of the beginning of early potato planting north of the 45°-limit shown on the chart. In the more southern districts planting dates range from the latter part of December in central Florida to about February 10 in the central Gulf States. The temperatures in these southern localities range from 50° (F.) in the northern portion to 60°(F.) in central Florida, as shown on figure 5. The 45°(F.) isotherm crosses the northern portion of the Gulf States about February 15 and moves thence northward simultaneously with the isochronal line of the beginning of early potato planting, to

tions of the country, but is generally from 54°(F.) to 57° (F.), or about 10° higher than for early potatoes and 15°(F.) higher than for spring wheat. Figure 7 shows the normal daily temperature for different sections of the country east of the Rocky Mountains at which corn planting begins on the average and also the dates on which this temperature is reached in the several localities. It will be noted that in a small area of the southern Great Plains corn planting begins while the normal daily temperature is from 3°(F.) to 5°(F.) lower than in other sections of the country, which causes a slight northward bend in the isochronal lines in that area. However, when it is considered that planting begins in the extreme South about 3 months earlier than in the northern border States, the uniformity in the planting temperatures for the various sections is noteworthy. It should also be noted that a mean daily temperature of 55°(F.) in spring corresponds to the average date of the last killing frost.[1]

[1] Cf. J. B. Kincer, Relation between Vegetative and Frostless Periods, MONTHLY WEATHER REVIEW, 1919, 47: 106-110.

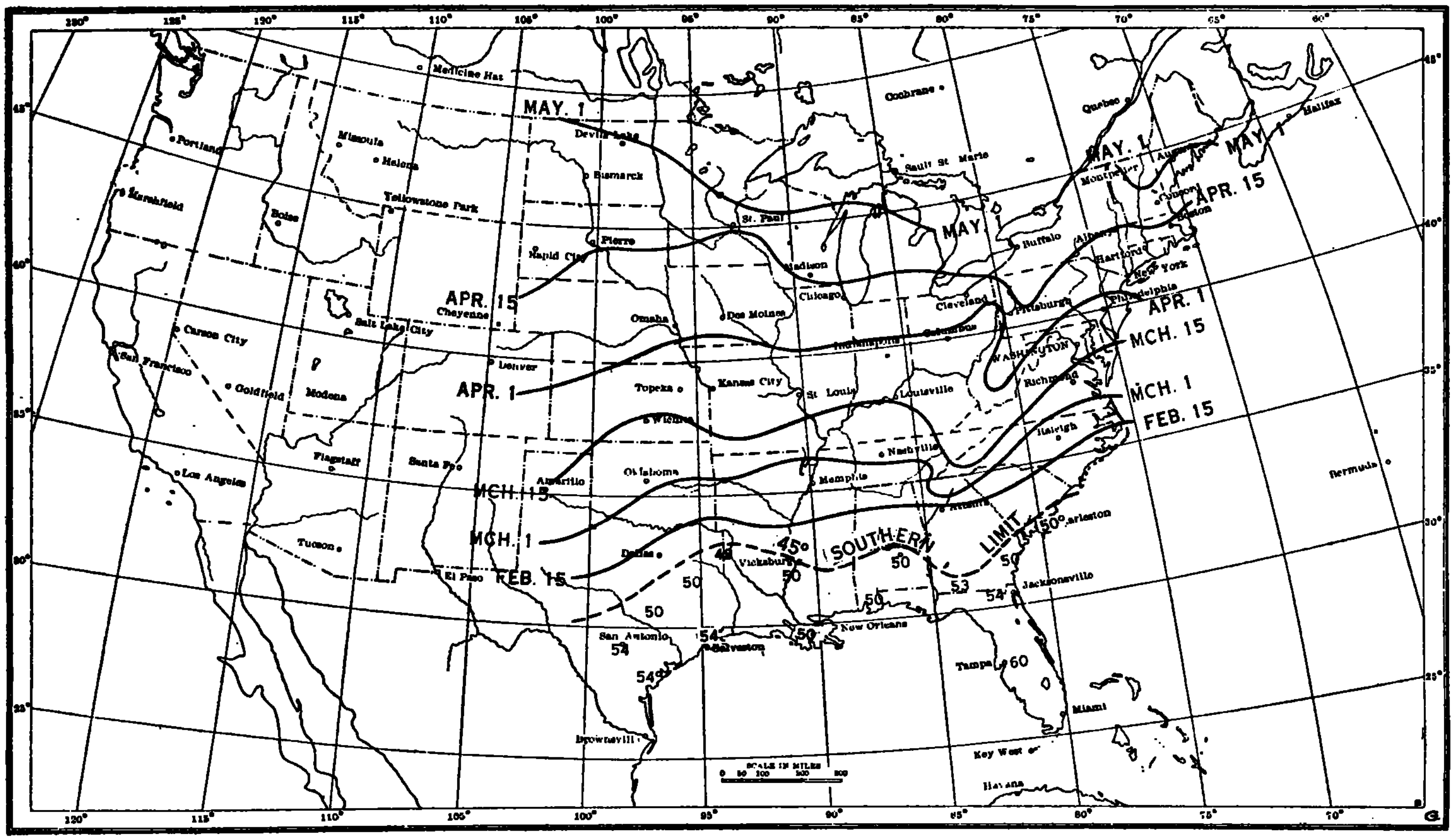

FIG. 5. Date in spring when the normal daily temperature rises to 45° (corresponding to the average date on which early potato seeding begins).

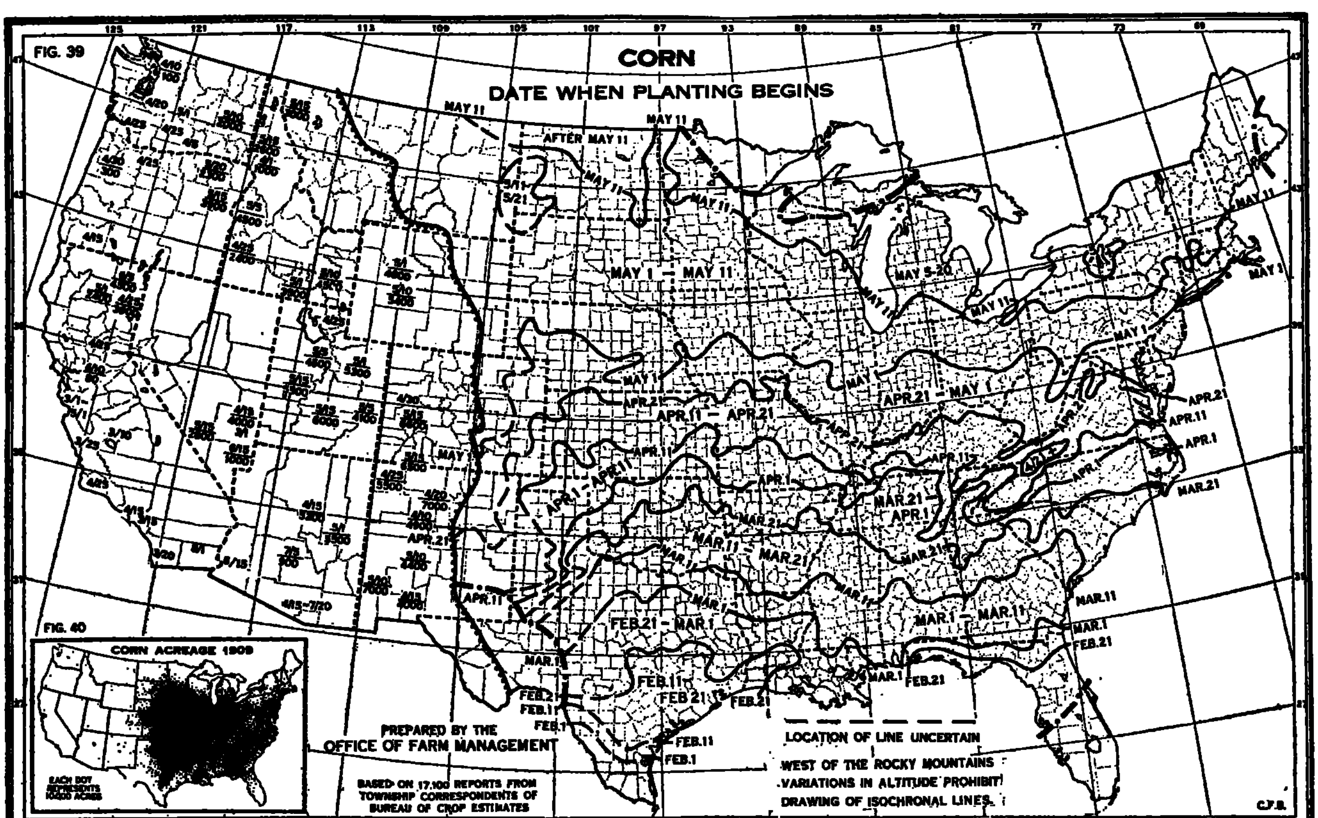

FIG. 6.

Therefore a map showing the average dates of the last killing frost in spring indicates also, approximately, the average dates of the beginning of corn planting.

COTTON.

Cotton requires for satisfactory germination and early growth more warmth than is required for any of the other staple crops grown in the United States. Cotton seed can not be planted until the soil is thoroughly warm, and consequently planting usually does not begin in the eastern portion of the belt until the normal daily temperature rises to 60°(F.) or 62°(F.), and not in the western portion until 61°(F.) to 63°(F.) is reached. Figure 9 shows the dates on which the temperature rises to these values in the different sections of the cotton belt, which corresponds to the average time when planting begins (see fig. 8).

Figures 10 to 13 show graphically the time of the beginning of planting and of harvest of the crops discussed above in their temperature and geographic relation. They represent a belt extending across the country from northern North Dakota southeastward to southern Georgia. Graph No. 1 (fig. 10) represents the area in North Dakota between Bismarck and Devils Lake; No. 2 (fig. 11), east central Nebraska; No. 3 (fig. 12), extreme western Tennessee; and No. 4 (fig. 13), southern Georgia between Macon and Thomasville.

The ends of the heavy arcs within the circles of each graph show, respectively, the time of the beginning of planting and of harvest of the several crops named. The figures within the circle show the annual march of temperature for the respective localities by 10-day intervals. This facilitates a comparison of the temperatures at which these operations begin in the different and widely

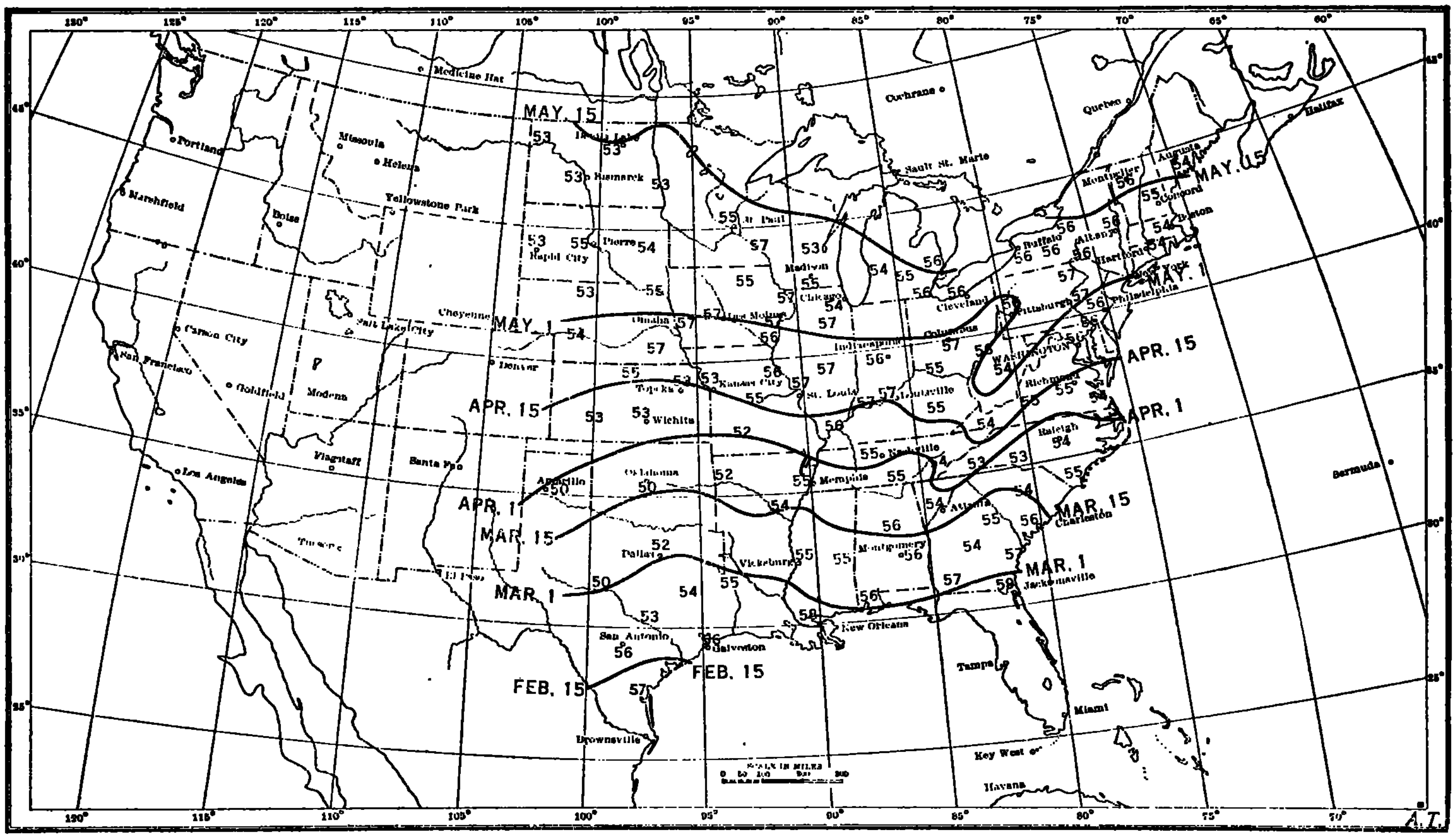

FIG. 7. Normal daily temperature at the average date of beginning of corn planting and the date on which this temperature is reached.

These dates vary from the first of March in extreme southern Texas to the last decade in April in the northern portion of the belt.

It is interesting to note the two extreme temperature requirements for planting the staple crops grown in the United States, spring wheat and cotton, the former coming into best development only in the northern portions of the country, and the latter only in the southern. We find that spring wheat may be planted when the normal daily temperature rises to 37°(F.), and that cotton as a rule will not germinate satisfactorily if planted before the daily temperature rises to 60°(F.). The fact that this country affords opportunity for the growing on a large commercial scale of these two important crops, requiring such a large difference in temperature conditions for successful development, emphasizes its geographic magnitude and diversity of climate.

separated localities. These graphs bring out in an interesting way the short space of time within which the staple spring crops must be planted in northern districts as compared with the southern section of the country. In northern North Dakota, for example, the planting of the four crops shown in figure 10 should begin within a period extending but slightly over one month, while in southern Georgia the beginning of planting of the several crops may extend over a period of about two and one-half months. It will be noted also that for a particular crop grown in each locality planting is begun at practically the same temperature. The harvesting of corn is shown as the time when cutting and shocking begin, which, however, is not the general method of harvest in all localities, but is the common practice in the dairy States of the North, also in Ohio, West Virginia, Maryland, Virginia, and portions of Kentucky and Missouri.

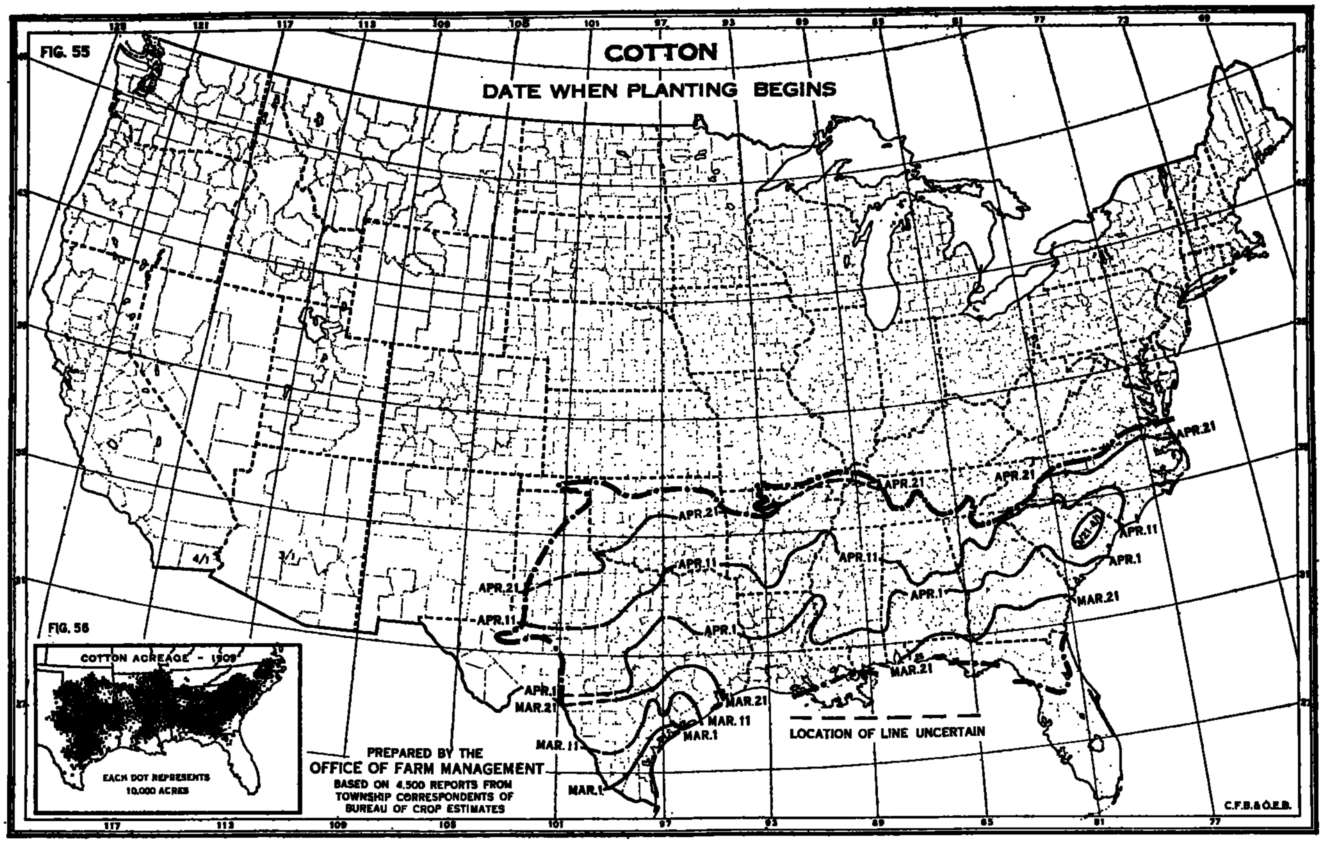

FIG. 8.

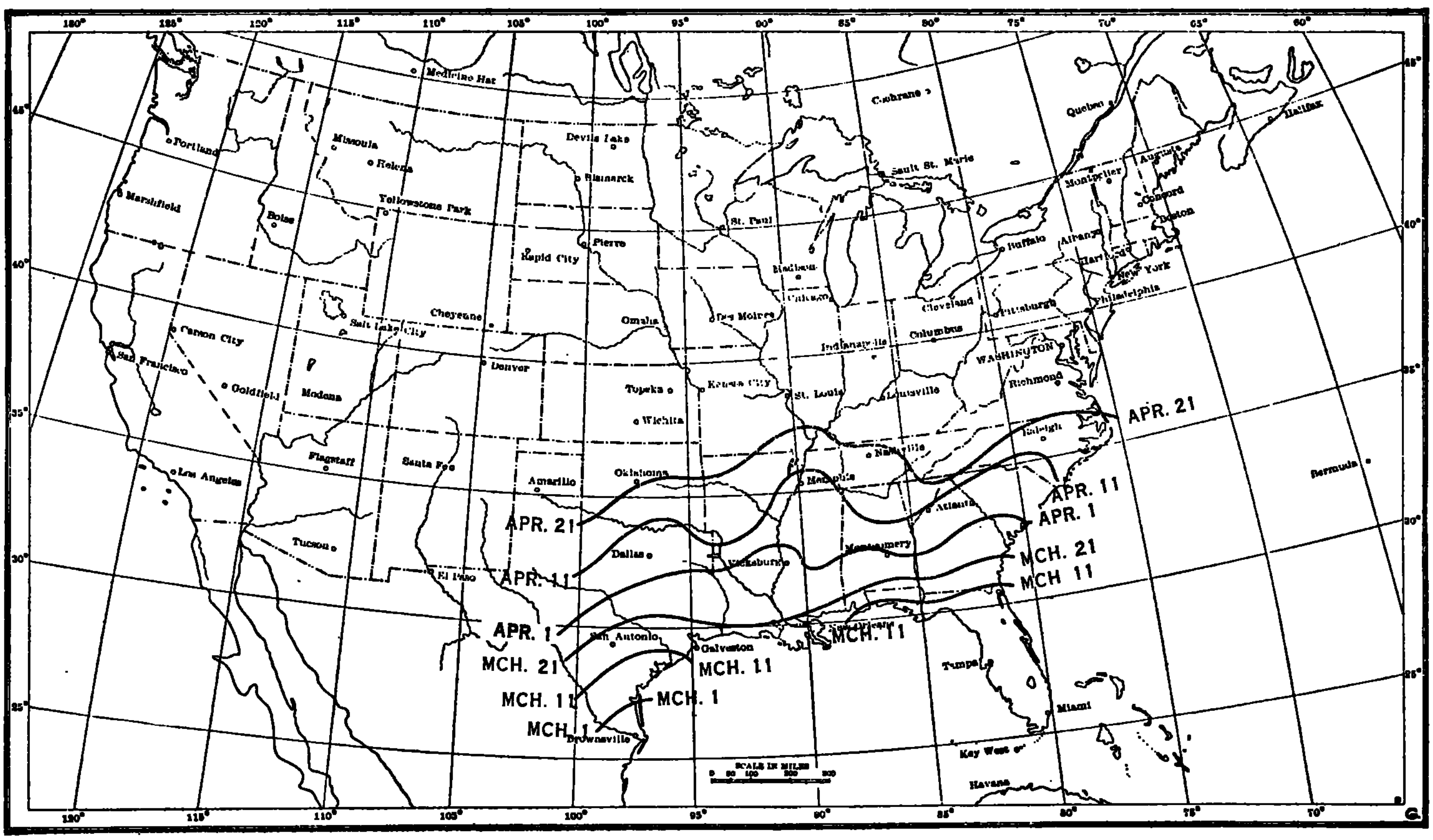

FIG. 9. Date in cotton belt on which the normal daily temperature rises to 63° west of the Mississippi River and to 60° east (corresponding to the average date on which cotton planting begins).

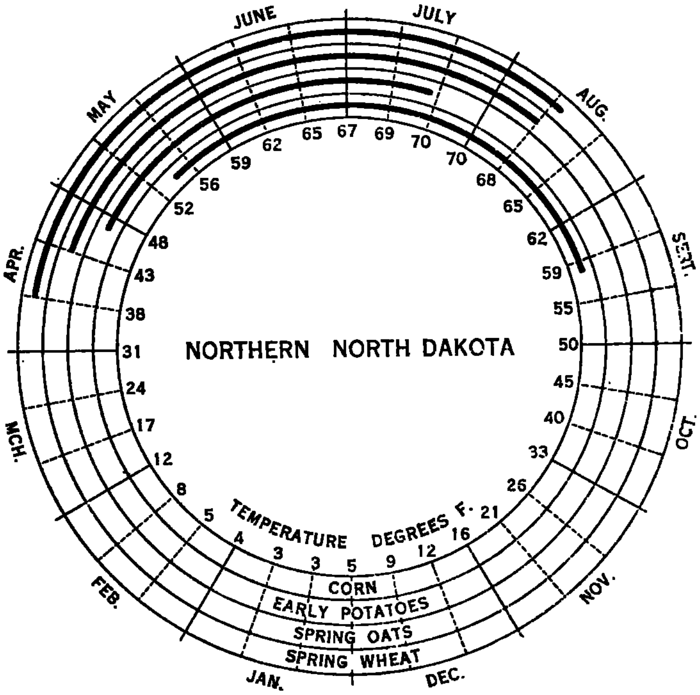

Fig. 10.

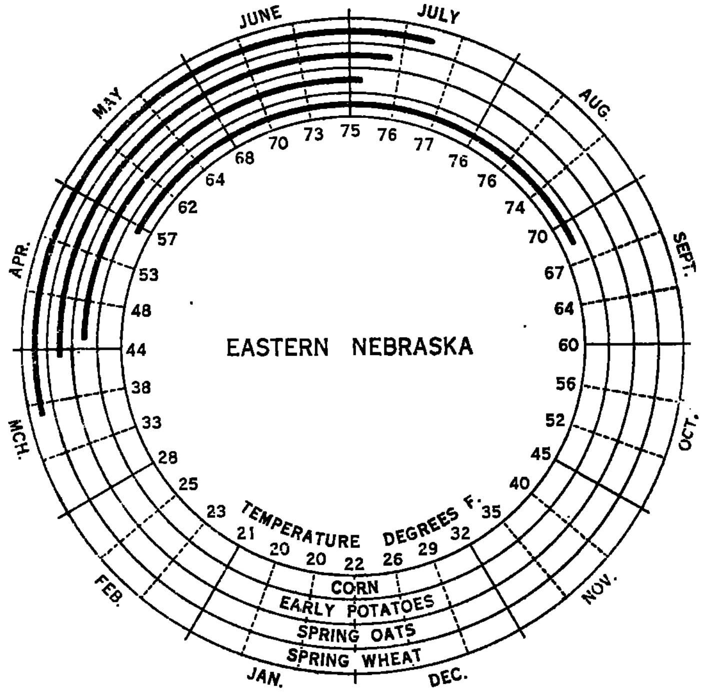

Fig. 11.

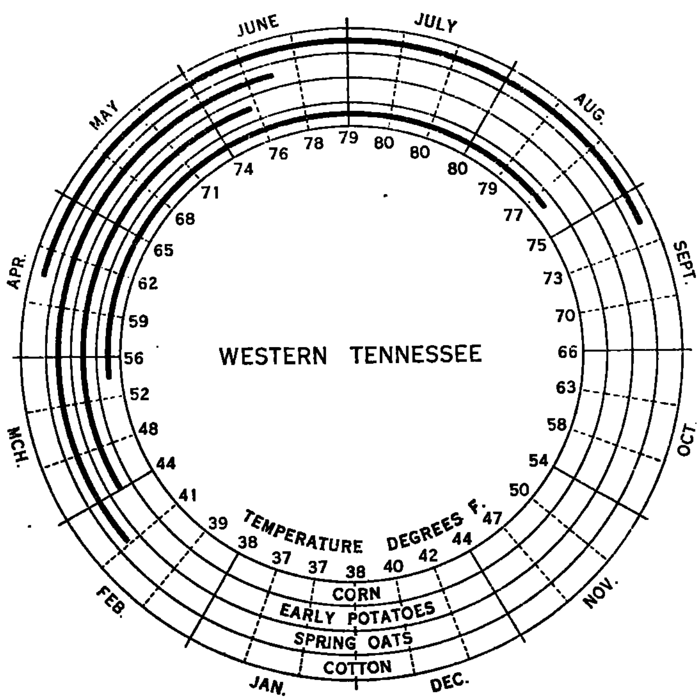

Fig. 12.

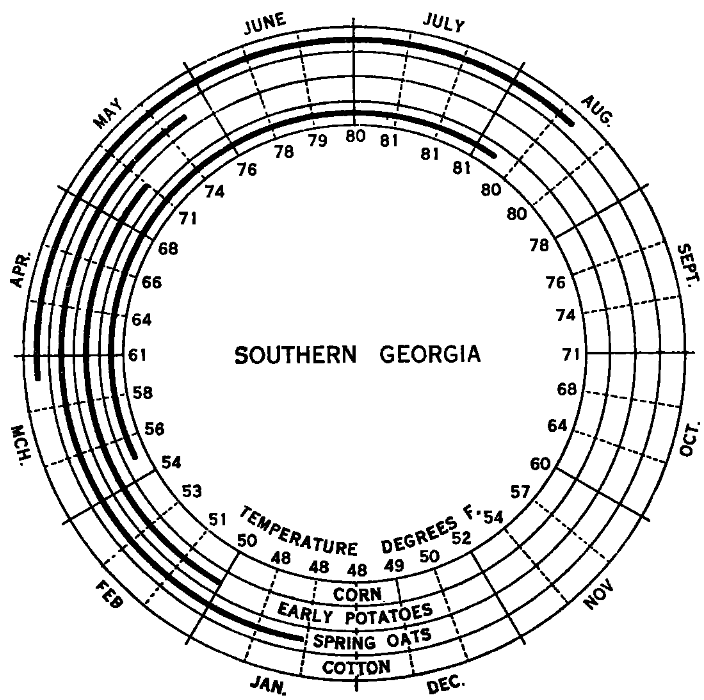

Fig. 13.

Figs. 10-13. Annual march of temperature by 10-day intervals and the time of beginning of planting and of harvest of certain crops.

THERMAL CONSTANT.[1]

Table 1 shows for various sections of the country the thermal constant for corn and spring oats, computed from the normal daily temperature from the average date of the beginning of planting to the average date of the beginning of harvest, as before indicated. The successful growth of corn is limited by temperature conditions, but to a decidedly less degree than is cotton. Owing to the fact that corn can not be planted until the mean daily temperature rises to about 55°(F.), the thermal constant above this value is not large enough in the extreme northern localities to bring the crop to maturity. This has been overcome to some extent, however, by planting quick maturing varieties, but even by this practice the crop is not commercially profitable in the northern tier of States, except in the southern portions of some of them. Very little corn is grown in the northeastern States, or north of a line extending from the central portion of the lower peninsula of Michigan through the central portions of Wisconsin and Minnesota; or in North Dakota and Montana, and from the Rocky Mountains westward.

TABLE 1.—*Thermal constant for corn and oats, selected localities.*

Localities.	Corn.	Spring oats.
Southern Michigan	1,416	1,887
Eastern South Dakota	1,592	2,018
Eastern Nebraska	1,811	2,016
Central Iowa	1,630	2,006
Central Illinois	1,932	2,164
Central Ohio	1,757	2,138
Southeastern Pennsylvania	1,995	2,204
East-central North Carolina	2,563	1,962
Eastern Tennessee	2,493	2,067
Central South Carolina	2,813	1,881
Central Alabama	2,700	1,845
Central Missouri	2,300	1,960
East-central Arkansas	2,864	2,069
Central Oklahoma	2,729	2,195
Eastern Texas	2,513	1,854

This table shows the accumulated day-degrees (F.) of temperature in excess of that at the average date of the beginning of planting until the average date of the beginning of harvest.

Table 1 shows that the thermal constant for corn in the principal producing areas ranges from 1600°(F.) to 1800°(F.), but farther north, in southern Michigan and eastern South Dakota for example, it is from 1400°(F.) to 1600°(F.), due to the planting of early-maturing varieties, as before indicated, and possibly due to some extent to the longer summer days in the North. In some southern localities where slower-maturing varieties are planted, it runs as high as 2800°(F.).

Table 2 shows for selected localities, representing a belt extending across the country from northwest to southeast, the potential thermal constant, or that available for corn development; that is, for the period extending from the average date of the beginning of planting to the average date of the first killing frost in fall. The record for Devils Lake shows clearly why corn can not be successfully grown in the extreme northern localities. The potential thermal constant for this locality is only 1260° (F.) while Table 1 shows that about 1600°(F.) is required for successful commercial growth. While the thermal constant is thus deficient in the North, it is interesting to note the large surplus available in the South; in southern Georgia, for example, the potential thermal constant is over 4000°(F.), which is more than double the amount necessary to mature the average variety of corn. Figure 14 contrasts graphically the potential thermal constant for the localities represented in Table 2.

TABLE 2.—*Accumulated day-degrees (F.) of temperature (thermal constant) by 10-day intervals, in excess of the normal daily temperature at the average date of the beginning of corn planting until the average date of the first killing frost in fall, selected stations.*

Devils Lake, N. Dak.		Lincoln, Nebr.		Memphis, Tenn.		Thomasville, Ga.	
	°(F.)		°(F.)		°(F.)		°(F.)
						Mch. 1-10	13
						Mch. 11-20	44
				Mch. 23-31	9	Mch. 21-31	100
				Apr. 1-10	48	Apr. 1-10	173
				Apr. 11-20	115	Apr. 11-20	270
				Apr. 21-30	214	Apr. 21-30	391
		May 1-10	25	May 1-10	344	May 1-10	537
May 15-20	3	May 11-20	83	May 11-20	501	May 11-20	708
May 21-31	42	May 21-31	184	May 21-31	701	May 21-31	915
June 1-10	110	June 1-10	307	June 1-10	909	June 1-10	1127
June 11-20	209	June 11-20	455	June 11-20	1137	June 11-20	1353
June 21-30	331	June 21-30	623	June 21-30	1383	June 21-30	1590
July 1-10	474	July 1-10	808	July 1-10	1634	July 1-10	1835
July 11-20	629	July 11-20	1005	July 11-20	1894	July 11-20	2085
July 21-31	800	July 21-31	1225	July 21-31	2180	July 21-31	2360
Aug. 1-10	945	Aug. 1-10	1418	Aug. 1-10	2434	Aug. 1-10	2610
Aug. 11-20	1069	Aug. 11-20	1594	Aug. 11-20	2679	Aug. 11-20	2850
Aug. 21-31	1176	Aug. 21-31	1760	Aug. 21-31	2929	Aug. 21-31	3104
Sept. 1-10	1241	Sept. 1-10	1878	Sept. 1-10	3131	Sept. 1-10	3321
Sept. 11-15	1260	Sept. 11-20	1962	Sept. 11-20	3314	Sept. 11-20	3521
		Sept. 21-30	2007	Sept. 21-30	3463	Sept. 21-30	3697
		Oct. 1-10	2017	Oct. 1-10	3579	Oct. 1-10	3845
		Oct. 11-13	2017	Oct. 11-20	3656	Oct. 11-20	3960
				Oct. 21-31	3694	Oct. 21-31	4045
				Nov. 1-2	3696	Nov. 1-10	4087
						Nov. 11-14	4096

It is also interesting to note that the large difference in the thermal constant for corn between the northern and the southern localities, as shown in Table 1, does not exist in the case of oats. The reason for this is that this

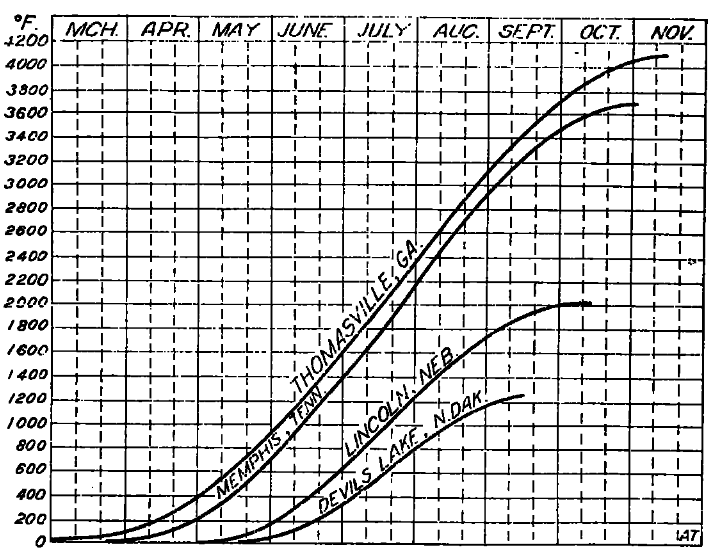

FIG. 14. The accumulated day-degrees of temperature for selected stations (thermal constant) in excess of the mean daily temperature at the beginning of corn planting until the average date of the first killing frost in fall (see Table 2).

crop is planted at temperatures about 12°(F.) lower than corn, and consequently the thermal constant is ample for maturity, making it unnecessary to develop special varieties, as in the case of corn.

The thermal constant for cotton computed from the mean daily temperature at the average date of the beginning of planting to the average date of the beginning of harvest in selected localities in the cotton belt is as fol-

[1] Cf. C. Hart Merriam, "Laws of temperature control of the geographic distribution of animals and plants." Nat'l Geogr. Mag., 1894, 6:229-238, 3 colored maps. (One of these maps, life zones, is reproduced as pl. I of vol. 37, Bull. Torrey Botanical Club.) A note by Dr. Merriam, Science, 1899, N. S., vol. 9, p. 116, says that, by mistake, the temperature summations published in the original table did not have 6° C. deducted when they were made. See also, C. H. Merriam, "Life zones and crop zones of the United States," Bull. 10, U. S. Biol. Surv. Part 3 is, "Laws of temperature control of the geographic distribution of plants and animals."

Dr. Merriam seems to have originated this temperature summation method from 6°C. as zero, for a close study of the biological effect of seasonal temperatures.—C. F. B.

lows: Raleigh, N. C., 1860°(F.); Thomasville, Ga., 1975° (F.); Montgomery, Ala., 1900°(F.); Little Rock, Ark., 1910°(F.); Oklahoma, Okla., 1820°(F.); and Galveston, Tex., 1810°(F.). The mean daily temperature at the average date of beginning of planting in these respective localities is: Raleigh, 60°(F.); Thomasville, 61°(F.); Montgomery, 62°(F.); Little Rock, 62°(F.); Oklahoma, 61°(F.); Galveston, 63°(F.). The area in which cotton can be successfully grown in commercial quantity has a well defined thermal limit. This limit is established by about 2000° thermal constant between the normal daily temperature at the beginning of planting and the average date of the first killing frost in fall as is shown by the records for the following localities near the northern limits of the belt: Norfolk, Va., 2010° (F.); Raleigh, N. C., 2190° (F.); Chattanooga, Tenn., 2000°(F.); Fort Smith, Ark., 2040°(F.); Oklahoma, Okla., 2140°(F.). Some cotton is grown a little north of Raleigh and Oklahoma, but very little north of the other points named (see fig. 8).

By comparing the thermal constant for cotton thus computed with that for corn in the principal corn belt

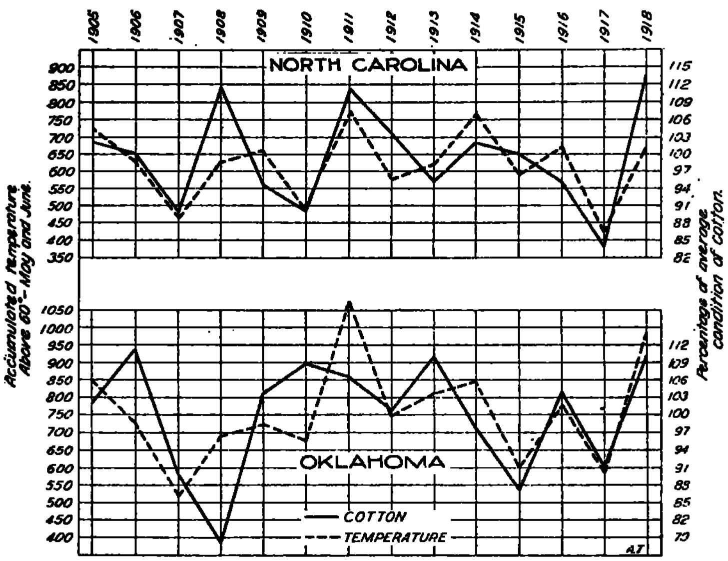

FIG. 15. Accumulated temperature above 60° (the normal mean daily temperature corresponding to the average date of beginning of cotton planting) for the months of May and June, and the condition of cotton on June 25 expressed in percentage of the average condition for the 14-year period, 1905–1918, as reported by the Bureau of Crop Estimates.

and, generally, for oats, as shown in Table 1 it will be seen that there is very little difference in the amount of heat necessary, when measured by accumulated temperature above the temperature at date of planting, to bring these different crops to maturity, notwithstanding oats is classed as a cool-weather crop. In the case of cotton, however, the plants continue to develop new fruit long after that first formed reaches maturity, thus requiring a longer growing season for production on a commercial scale. For successful germination and satisfactory growth in its early stages of development cotton requires also a comparatively warm spring, particularly in the northern portions of the belt where temperatures are normally lower than farther south. Figure 15 shows for North Carolina and Oklahoma for the months of May and June, and for each year from 1905 to 1918, inclusive, the accumulated temperature above 60°(F.) (the temperature at which cotton planting usually begins), and also the condition of cotton on June 25, expressed in percentages of the 14-year average condition, as reported by the Bureau of Crop Estimates. The solid lines show the condition of cotton and the broken lines the accumulated temperature. It will be seen from these graphs that, in general, there is a close relation between the temperature conditions during May and June and the condition of cotton at the close of the latter month.

There is also a well-defined relation between the June temperature and the condition of corn at the close of that month, as is indicated by Table 3 and figures 16 to 19. Table 3 shows for the States of Iowa, Illinois, Indiana, and Ohio the accumulated temperature above 55°(F.)

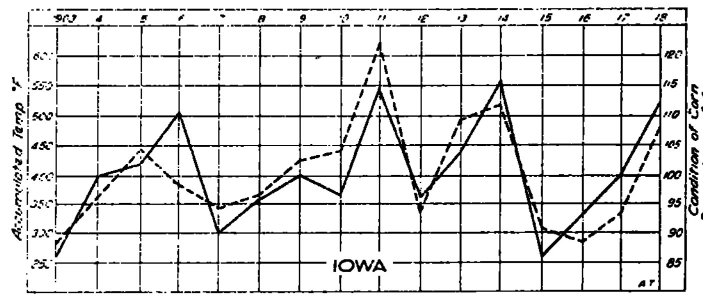

FIG. 16.

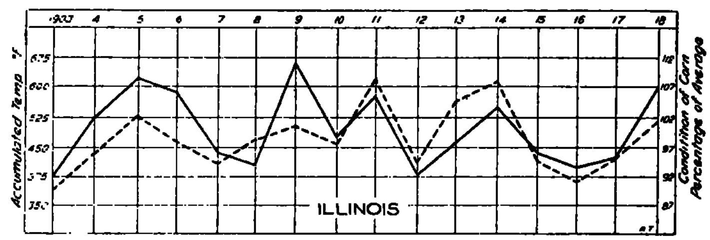

FIG. 17.

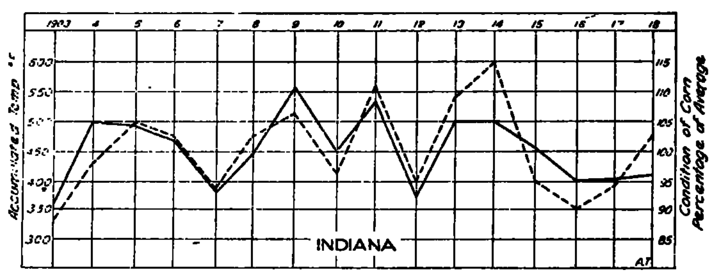

FIG. 18.

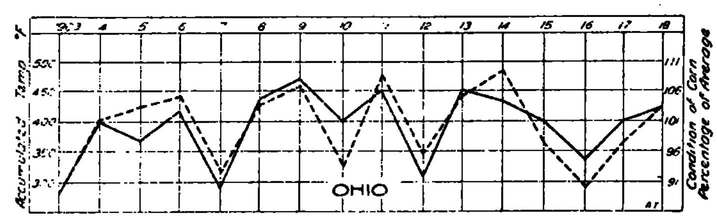

FIG. 19.

FIGS. 16 to 19, inclusive, show, for the States of Iowa, Illinois, Indiana, and Ohio, the accumulated temperature above 55° (the normal daily temperature at the average date of beginning of corn planting) for the month of June, and also the condition of corn on July 1, expressed in percentage of the average condition for the 16-year period 1903–1918, as reported by the Bureau of Crop Estimates (see Table 3). [— corn; .. temperature.]

(the normal mean daily temperature at the average date of the beginning of corn planting) for the month of June, and also the condition of corn on July 1, expressed in percentage of the average condition for the 16-year period 1903–1918, as reported by the Bureau of Crop Estimates. It will be seen from these graphs that in most cases there is a very close relation between the June temperature and the condition of corn on July 1, as thus reported.

It is also of interest to note the effect of temperature on the germination of corn, as indicated by figure 20. The solid line in this graph shows the number of days required for corn to come up at Wauseon, Ohio, for the period from 1883 to 1912, while the dash line shows the average daily temperature in excess of 55° (F.) during the period required, after planting, for it to appear above ground in each year. The records on which this graph is based were made by Mr. Thomas Mikesell, of Wauseon, Ohio; they appear in Supplement No. 2, MONTHLY WEATHER REVIEW, September, 1915. It will be noted that when the temperature averaged only slightly above 55°(F.), a comparatively long time was required for germination, but with an average of 65° (F.), or above, corn came up usually in about seven days or less.

Some interesting results are obtained from a study of the thermal constant for spring wheat. This alone of the staple crops is usually planted before the advent of the vegetative period, which corresponds to a normal daily temperature of 6°C. (42.8°F.).[1] As previously stated, seeding usually begins in the western portion (Dakotas and Nebraska) of the spring-wheat belt when the mean daily temperature rises to 37°(F.) and in the eastern (Minnesota and Wisconsin) when 40°(F.) is reached. Computing the thermal constant from these temperatures until the beginning of harvest for different portions of the belt, we find the following results: Bismarck, N. Dak., 2700°(F.); Huron, S. Dak., 2680°(F.); Moorhead, Minn., 2660°(F.); and Madison, Wis., 2300°(F.). It will be noted that these are much higher than for the other crops discussed, if we consider for corn the average variety grown in the central districts. However, if we compute the thermal constant for spring wheat from a 43°(F.) temperature base, or the beginning of the vegetative period, the following results are obtained: Bismarck, 1970°(F.); Huron, 1970°(F.); Moorhead, 1940°(F.); and Madison, 1980°(F.), which is in agreement with the values for other crops considered.

TABLE 3.—*Accumulated temperature above 55°(F.) for the month of June, and the condition of corn on July 1, expressed in percentage of the average condition for the 16-year period 1903–1918, as reported by the Bureau of Crop Estimates, Department of Agriculture. (See figures 16 to 19.)*

Year.	Iowa.		Illinois.		Indiana.		Ohio.	
	Accumulated temperature.	Condition of corn.	Accumulated temperature.	Condition of corn.	Accumulated temperature.	Condition of corn.	Accumulated temperature.	Condition of corn.
1903	288	86	339	92	333	91	282	89
1904	363	100	441	102	438	105	402	101
1905	447	102	528	109	501	104	426	98
1906	387	111	465	106	477	102	444	103
1907	345	90	402	96	387	93	318	90
1908	363	96	465	94	474	99	426	104
1909	423	100	507	111	516	111	453	108
1910	435	97	453	99	408	100	327	101
1911	621	114	615	105	555	108	477	106
1912	336	96	402	92	399	92	348	92
1913	495	103	567	98	546	105	444	106
1914	516	116	615	104	600	105	483	104
1915	303	86	405	96	402	101	354	101
1916	285	93	366	94	348	95	291	94
1917	330	100	405	95	393	95	357	101
1918	474	112	513	107	474	96	414	103

The question of the difference in air temperature and the temperature of the soil near the surface where germination is effected is one of considerable importance in studying the relation of air temperature to planting dates as outlined on the basis of the Wauseon records. Observations of soil temperature at Lincoln, Nebr., made during the period from 1888 to 1902, published in the sixteenth annual report of the Nebraska Agricultural Experiment Station, January, 1903, pages 95–102, show that the soil temperature during the spring months at 2 or 3 inches below the surface at that point is usually 5 or 6 degrees higher than that of the air. At this season of

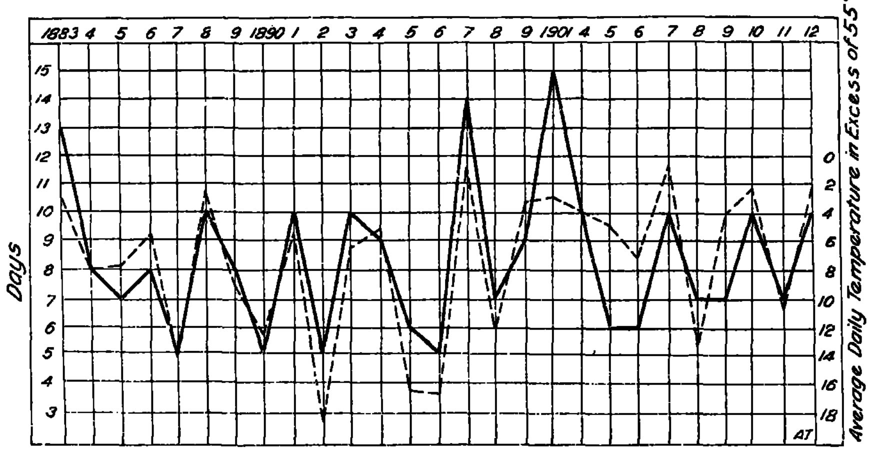

FIG. 20. Number of days from corn planting till plants appeared above the ground and the average daily excess of temperature above 55° for those days in each year. From records made by Mr. Thomas Mikesell at Wauseon, Ohio (records were incomplete for 1900, 1902, and 1903). [— days; .... temperature.]

the year the normal rise in air temperature is about 10° (F.) a month; hence, with this difference between the soil and air temperatures, the former would rise to a given value about two weeks earlier than the latter.

Sachs determined the minimum, optimum, and maximum temperatures for germination of wheat, barley, pumpkins, beans, and corn to be as follows: [1]

Plant.	Minimum.	Optimum.	Maximum.
	° F.	° F.	° F.
Wheat	41	83.7	108.5
Barley	41	83.7	99.9
Pumpkin	56.7	92.7	115.2
Beans	49.1	92.7	115.2
Corn	49.1	92.7	115.2

It appears from the above, and the conclusions of other investigators, that the optimum temperature for a considerable number of plants is between 83° and 95°(F.). In considering the minimum temperature of germination in its relation to safe or usual planting dates from year to year, however, the short period fluctuations, or temperature variability, plays an important part. The characteristic alternations of cool and warm periods serve in the long run to advance the date of the normal daily temperature at which germination will take place to a season earlier than planting can safely be accomplished. If corn, for example, should be planted in spring as soon as the soil temperature rises to 49° or 50°(F.), or even the normal air temperature rises to that value, there would often follow a period too cool for germination, resulting in the decay of seeds.

Some experiments have been made by H. N. Vinall and H. R. Reed, of the Bureau of Plant Industry, to determine the effect of weather on the growth of sorghums

[1] Ibid., cf. also J. B. Kincer, loc. cit.

[1] From Vinall, H. N., and Reed, H. R., "Effect of temperature and other meteorological factors on the growth of sorghums," Jour. Agr. Research, 1918, 13: 133-147.

under widely varying climatic conditions.[1] Observations were made at Puyallup, Wash.; Chico, Berkeley, Bard, Chula Vista, and Pasadena, Cal.; and Chillicothe, Tex. The authors summarize as follows:

(1) Sorghum is semitropical in its adaptations and does not thrive in regions of low temperatures.

(2) Sunshine is probably an important factor of growth, as evidenced by the difference of growth at Chula Vista, Calif., and Puyallup, Wash., where the mean temperatures and the total positive heat units available are but little different.

(3) The "physiological constant" for the ripening phase of sorghums according to Linsser's law of growth is about 0.53.

(4) Extremely high temperatures during the period of flowering and fruiting result in a decreased yield of seed.

(5) The date of planting should be so arranged that germination and early growth of the plants will take place during the period of high temperatures, and the flowering and fruiting when more moderate temperatures prevail.

(6) Adverse weather conditions affect such supposedly stable characters as the number of leaves per plant, as well as the volume of growth.

Linsser's law and its application to the matter in hand are given as follows:

"In two different localities the sums of positive daily temperatures for the same phase of vegetation is proportional to the annual sum total of all positive temperatures for the respective localities—that is, the heat required in any locality to produce a given phase of development in vegetation bears a constant ratio to the total positive heat units available in that place. This ratio has been styled the "physiological constant." If 50° (F.) is considered as the minimum temperature for growth in the sorghums, the yearly total of positive heat units at Chillicothe in 1915 was 5618° (F.); at Bard, 1915, 7989°; and at Chula Vista, 1916, 3600°. The positive heat unit required to bring the sorghums to maturity at Chillicothe were 3028° (F.), at Bard, 4236°, and at Chula Vista, 1,895°. It appears, therefore, that the physiological constant of sorghum for the period from planting to maturity is about 0.53. The conformance of the sorghums in these three cases to Linsser's law is rather remarkable, the exact ratio in each case being as follows:

Chillicothe	3,028; 5,618; or 0.539
Bard	4,236; 7,989; or 0.530
Chula Vista	1,895; 3,600; or 0.526

[1] Ibid.

"Although Linsser's law seems to furnish a rule for the behavior of sorghums in respect to temperature, it does not take into account the effect of sunlight and other factors, which are also important."

Prof. Livingston has proposed a method by which both the moisture and temperature factors as affecting the growth of plants may be expressed as a single numerical value. The index thus proposed is the product of three factors—rainfall, evaporation, and temperature. (See Physiological Researches, vol. 1, No. 9, May, 1916, where the method employed is set forth in detail.) The indices proposed by this method are simply the product obtained by multiplying Transeau's rainfall-evaporation ratio [1] or the ratio of annual rainfall to annual evaporation for the period in question, by the summation index of temperature efficiency for the same period. He employs the physiological indices of temperature as derived from Lehenbauer's [2] results. This system, which takes into account the general principle of temperature minima, optima, and maxima, as related to plant growth, is described in Physiological Researches, volume 1, No. 8, pages 399–420, April, 1916.

A chart is presented in volume 1, No. 9 (ibid.), showing for the average frostless season a climatic zonation of the United States, based on the moisture-temperature indices as thus computed. The chart shows a very high potential climatic efficiency in the Gulf Coast region, where the supply of heat and moisture is great and the frostless season long, with rapid decrease northward and northwestward. The indices range numerically from 23,000 in central Florida to about 200 in portions of the central plateau districts of the West.

The high value of climatic efficiency obtained in the more southern localities by the Livingston method is due largely to the long frostless season in that area and the method used in combining the moisture and temperature factors. By taking the product of the two factors for a given period the resulting values increase rapidly with an increase of either factor and much more rapidly when both factors are raised. Thus, an increase of 100 per cent in one factor elevates the final result by a like amount, while an increase of 100 per cent in both factors results in an indicated climatic efficiency value fourfold greater.

[1] Transeau, E. N., Forests of Eastern America. Amer. Nat. 39: 875–898, 1905.
[2] Lehenbauer, P. A., Growth of maize seedlings in relation to temperature, Phys. Res. 1: 247–288, 1914.

A GRAPHIC SUMMARY OF SEASONAL WORK ON FARM CROPS.

By O. E. BAKER, C. F. BROOKS, and R. G. HAINSWORTH.

[Separate 758, Yearbook, U. S. Dept. Agric., 1917 (pp. 537–589. 90 figs.). Abstracted and discussed.]

"This study contains maps showing the dates when planting, harvesting, and other operations are performed in the culture of the staple crops in different parts of the United States, and also graphs showing the seasonal distribution of labor by 10-day periods on typical farms in several important agricultural regions. Inscriptions under the maps afford information as to the hours of labor per acre required in growing the staple crops in various sections of the country."

Fifty-four maps show the usual dates when the most important operations are performed on winter wheat, spring wheat, winter oats, spring oats, corn, kafir corn, timothy, and clover, alfalfa, cotton, early potatoes, late potatoes (northern commercial crop), sugar beets, field beans, tobacco, Elberta peach, Ben Davis apple, strawberries, and tomatoes.

In preparing these maps, "the dates for each operation were entered from the schedules returned by the township reporters on large county outline maps of the States. The altitude reported on each schedule was indicated also. In making the general maps showing dates by isochronal lines, a strict use of the individual reports was not possible. This is because there is for many crop operations a wide range of dates in the reports received from a county. Such differences are due (1) to the physical conditions, such as temperature, slope, drainage, and soils on each farm; (2) to the individual practice of the farmer; and (3) to the difficulty of estimating for